Allen Thomson
1857 ?

V. *On Unusual Mobility of the Iris, his own case.* By JOHN PAXTON, M.D., Kilmarnock, with Remarks by Dr. ALLEN THOMSON, in a Letter to the Editor.

(*Read before the Medico-Chirurgical Society of Glasgow.*)

GLASGOW COLLEGE, *August* 1, 1856.

DEAR SIR,—I send you herewith Dr. Paxton's interesting account of his own case, in which he describes the peculiar state into which his eyes are liable to fall, and his unusual power of contracting and dilating the pupil.

Dr. Paxton's case appears to present three peculiarities at least, viz.: first, in the liability of the eye to fall completely out of adjustment for distinct vision at any distance, or what appears to be a state of complete relaxation; second, in the unusual facility with which he adjusts the eye for near and distant objects; and third, in the considerable amount of voluntary power over the motions of the iris, independently, as it would seem, of any effort of adjustment to a special object.

The first peculiarity may be somewhat similar to that to which many persons are more or less subject in certain states of the eye, more especially, as Dr. Paxton remarks, in the coming on of reverie, sleep, &c. I have not had opportunities of knowing whether there are other cases of the same kind as Dr. Paxton's on record, and I should like to hear what Dr. Mackenzie or experienced practical oculists might say of this subject.

As to the second peculiarity, or the great power of altering the adjustment in Dr. Paxton's case, I think we may consider that power, or the necessity for its exertion, as connected in some measure in its origin with the state of paralysis into which the eyes were thrown by his accident. Dr. Paxton's observations appear important, as confirming the view generally held, that the motion of adjustment for near vision, which is always attended with contraction of the pupil, is the one which is accompanied by a feeling of effort, while the change for distant vision, attended with dilatation of the pupil, seems as if it were rather a return to a state of relaxation, or is unattended with perceptible effort. This entirely agrees with what I observe in myself, whether in using both eyes or only one; and it indicates how closely the change of adjustment is connected with the third pair, and that Dr. Paxton's affection may have been a partial paralysis of that nerve.

The third peculiarity, or the voluntary power to alter the pupil, or alternately to contract and dilate it, without any apparent effort for adjustment, is the part of the case which, as you know, might occasion the greatest difficulty and difference of opinion.

The motions of the iris and of the ciliary muscle, which I believe to be most immediately concerned in producing the adjustment of the eye to vision of objects at different distances, are of an associated kind, and whether both eyes or only one eye are used, are generally, if not always, accompanied by action of some of the external muscles of the eyeball, probably the internal and inferior recti, and the inferior oblique muscles. Now, as we see very great differences in the degree to which, among other muscles of the body universally recognised as voluntary, the power exists of directing the effort of the will separately to the individual muscles of certain groups, and as the iris is subject to voluntary influence in some animals, I do not see why, in so far at least as the operation of the voluntary power is concerned, the iris and

ciliary muscle should be considered as acting altogether differently from other associated muscles. In Dr. Paxton there appears to be an unusual degree of this separating power; but he informed me that although, in producing the motions of contraction or dilatation of the pupil, he did not actually make an effort of adjustment, or attempt to fix the eye alternately on a near and distant object, yet the effort to make either of these motions seemed to him, as it were, very similar to the motions for adjustment.

Dr. Paxton kindly showed me the motions of his iris, alternately contracting and dilating the pupil to a great extent with apparent ease at will. The pupil in his eye is not naturally large when at rest; the change of diameter in ordinary dilatation amounted to about a third, and in the contraction to somewhat less, but in complete dilatation to a greater extent. The statements which accompany Dr. Paxton's history of his case, are answers to some queries which I addressed to him with the view of endeavouring to bring out more fully those circumstances in the case which appeared to me of greatest physiological interest.

I have to thank Dr. Paxton for his great courtesy in replying to these queries, and to express my regret at having retained his papers so long. I have not had time to attend to this interesting subject since I first received Dr. Paxton's papers, and saw the motions of his pupils. Perhaps he may since have made further observations and experiments on them. The results of these it will give me great pleasure to learn.—I am, &c.,

ALLEN THOMSON.

To DR. GEORGE BUCHANAN.

Thirty-six years ago, when about eight years of age, and amusing myself in skating, I was suddenly thrown down with great force, in such a way that the forehead came in violent contact with the ice.

The immediate consequences did not seem serious, but in a short time swelling took place within the nasal passages, so that I could not breathe through the nostrils; squinting and double vision followed, and along with these a dilated condition of the pupils.

This was accompanied by an indistinct state of vision, which I cannot better describe than by comparing the appearance of a page of ordinary print, as seen during its continuance, to that of a page of Hebrew printing seen distinctly, namely, a series of dark marks conveying no meaning to me. With these symptoms coincided failing strength and a gradual falling off in flesh. I was supposed to be dying of head disease, and had become so weak as to be mostly confined to bed, when one evening a younger brother coming in beside me to amuse me, fell so that his head came into pretty smart contact with my forehead. This was considered at the moment a sad aggravation of my misfortunes, as it was thought

that if one blow had proved so injurious, a second would be likely to kill me outright. Next morning, however, I found I had regained the power of distinct vision, a considerable discharge of matter of an unhealthy character took place from the nostrils, the squinting and double vision disappeared, the power of breathing through the nose returned, and health was gradually restored.

The duration of the whole illness was about two months, and the second blow was received about three weeks after the first.

Ever since that time I have retained the power of reproducing the indistinct vision at will, and on asking a friend to observe what, if any, change occurred in the eye during the state of indistinct vision, he found that it coincided with a dilated condition of the pupil, and that the return to distinct vision coincided with a contracted state.

The producing of the indistinct vision conveys to me the sensation of the eyes becoming congested, and as if a fluid were falling into them, so that they become fuller; the recovery of distinct vision, on the other hand, is as if they were braced up by a very slight muscular effort.

Having thus given you a slight sketch of the history and present condition of the peculiarity of vision occurring in my own person, I shall now attempt to describe to you a few of the phenomena which it presents, as answers to the following queries drawn up and submitted to me by Professor Allen Thomson:—

1st. Whether in its ordinary state the eye is naturally adjusted for the vision of near objects, as for reading, or whether it is always conscious of an effort for adjustment to look at near objects?—In ordinary vision my eye is like any eye in a normal condition, *i. e.* in a state to look at either distant or near objects indifferently, within certain limits; if the object looked at be near or very small, then I am quite conscious of an effort at adjustment, but this effort is different from that by which I restore distinct vision, when I have allowed the pupils to fall into the dilated condition.

2nd. Whether I can with equal ease begin by contracting, and then dilate the pupil, or dilate first and afterwards contract it, and whether I am most sensible of effort in contracting or dilating the pupil?—The condition of moderate contraction of the pupil being the natural one in my eye, I must always begin by dilating, but can, with equal ease in showing it, begin with either the one or the other, as I have only, before calling attention to the pupils, to allow the condition that I *will* to occur, and then show the reverse taking place.

3rd. Whether I can produce either contraction or dilatation without a direct attempt at adjustment for near and more distant objects; or whether I require either actually to make such an adjustment, or to imitate the motions necessary for inducing it, in order to produce the contraction or dilatation of the pupil?—In answer to this question, I am almost inclined to think that I

possess voluntary power over the motion of the iris, because I can produce either contraction or dilatation, with the accompanying state of vision, while looking at the same object, whether that be the point of a pen I may be writing with, or a tree a mile distant.

4th. Whether, in first waking from sleep, I require any effort for adjustment for ordinary vision?—In waking from sleep, I am conscious of having the eyes always adjusted for distinct vision.

5th. Whether the eye is disposed spontaneously to fall out of adjustment, and to what extent it is so? Whether the state of the general health has any influence on the state of the eyes?—The state of health has no effect on the eyes. They are not disposed to fall out of adjustment when I am in an active state of body. They sometimes do so, however, while staring in vacancy, as in a state of reverie; but in that case, and with the eyes not fixed on any object, they can be adjusted instantly by the slight effort before mentioned.

6th. Whether I had tried the effect of belladonna on the eye?—The inconvenience to me in my professional avocations which would attend this experiment, has always deterred me from trying the effects of any medicine having the power of inducing mydriasis.

7th. Whether the effect of convex and concave glasses is the same in myself as in other persons, and, more especially, what is the effect of using a convex lens when the eye has fallen out of adjustment? If possible, to ascertain what strength of lens is equivalent to the ordinary power of restoring the adjustment.—The effect of convex and concave glasses is the same in my own as on eyes in the normal condition. Within the last three years I have been under the necessity of using very slightly convex spectacles; prior to this my sight had been excellent. When the pupil is dilated, and the vision in its indistinct state, concave glasses increase the defect; convex glasses, on the other hand, remedy it in proportion as their focal distance is the shorter, till, with a lens of the focal length of sixteen inches, the convexity compensates, as nearly as possible, for the maladjustment; more convex than this, they cause indistinct vision in proportion as their focal distance is decreased.

I have only further to add, that since these questions were put by Professor Thomson, I find that when I close one eye by pressing down the eyelid with the finger, I retain the power of producing these conditions of vision with the other; but when it is shut without the assistance of the finger, I find that I lose this abnormal control over the iris altogether.*

* Since writing the above notes, my attention has been called to a very similar case occurring in the person of and related by Dr. Roget in a letter to Mr. Travers, and by him published in his works on diseases of the eye, (London, 1820,) at page 72.

VI. *Further Remarks on Dr. Paxton's Case, with Observations on the Structure and Action of the parts concerned in the Focal Adjustment of the Eye.* By Allen Thomson, M.D., F.R.SS. L. & E., and Professor of Anatomy in the University of Glasgow.

The foregoing case is undoubtedly a rare and interesting one, not only on account of the extent of the contracting and dilating power in the iris which Dr. Paxton possesses, but also in that more remarkable state of complete dilatation or relaxation of the internal muscular structure of the eye which he is capable of inducing, so as to allow the eye to fall completely out of adjustment for distinct vision at any distance. Its pathological history also possesses some interest from the contrast which it presents with the more frequent result of external injuries by blows upon the eye or parts in its vicinity, which are liable to be attended, either directly or mediately, with amaurosis or affections of the optic nerve, and with a greater or less extent of paralysis in the third or other nerves. In this case the nerves regulating the internal movements of the eye appear to have been affected, but only in a peculiar manner, and in a very slight degree; and from the complete recovery that has taken place, the injury seems ultimately to have resulted rather in an increase than a diminution of the power of the internal muscular parts of the eye.

The case suggests several interesting subjects for remark, both of a physiological and pathological kind; but to give these their full value, the unusual phenomena presented by Dr. Paxton's eyes would require a more careful experimental study and observation than I have yet had an opportunity of instituting upon them.

In the meantime, it has appeared to me that it may not be unacceptable to the readers of this Journal to have placed before them, in connection with this case, a notice of the most recent observations of anatomists and physiologists, bearing upon the history of the structure and actions of those parts of the eye which appear to be involved in the peculiarities of Dr. Paxton's case. These facts, with the accompanying remarks, may be stated under the following heads, viz.:—

1st. The structure of the internal muscular apparatus of the eye, or of the iris and ciliary muscle.

2nd. The phenomena of the physiological action of these parts as directly observed in them, as influenced by the nerves, and as modified by narcotics.

3rd. The relation of the action of these parts to the change in the focal adjustment of the eye for vision at different distances.

1. *Structure of the Iris and Ciliary Muscle.*

A microscopic examination of the structure of the iris has shown that its fibrous substance consists mainly of two kinds of texture,

viz., a basement substance of binding tissue containing nuclei, and the contractile or muscular tissue. With regard to this last much doubt has prevailed, but the more accurate knowledge obtained of the different forms of the muscular structure in recent times, and more especially by the researches of Kölliker, together with the result of physiological experiment, have established, in the most certain manner, the muscular nature of the iris. The muscular fibres are arranged in two sets, viz., the circular and the radiating. The circular, sphincter, or orbicular muscle of the pupil forms a narrow ring of circular fibres, which surround the margin of the pupil, to the breadth of between $\frac{1}{40}$ and $\frac{1}{50}$ of an inch, and which may be most easily observed from the posterior surface when the pigment layer of the iris has been removed. The radiating fibres have been described by Kölliker as passing from the circular band, with the outer margin of which they are continuous, in a spreading and reticulated manner towards the external margin of the iris. They are often more scattered and more mingled with the basement tissue of the iris than the circular muscle; but a microscopic examination of these fibres leaves no doubt as to their being of the same nature with the circular fibres, and both of them bear a close analogy to the texture of which the longitudinal and circular layers of muscular substance of the alimentary canal is formed. The muscular fibres of the iris in man and mammiferous animals are, therefore, of the unstriated kind, which Kölliker believed he had succeeded in resolving by the action of diluted sulphuric acid into elongated nucleated cells.

Mr. Joseph Lister has more recently given a description of the results of a careful examination of the circular and radiating fibres of the iris, which he has made in man and some animals (Journal of Microscopic Science, vol. i., p. 8: 1852), which fully confirms the view previously taken by Bowman on less sure grounds, and extends and confirms the observations of Kölliker. According to Mr. Lister, it is quite easy to demonstrate the separate cells of the muscular texture in the sphincter of the pupil, and the same structure may be detected in the radiating fibres. Mr. Lister has given very clear representations of these fibre cells.*

In several specimens of the human iris, I have satisfied myself, by microscopic examination with an object lens of one-fifth of an

* I do not enter here into the discussion of the question recently raised by Professor Ellis (Proceedings of Royal Society of London, June, 1856, p. 212), as to the existence of the elongated cells of the unstriated muscular fibres described by Kolliker. Whatever may be the result of farther inquiry into this point, no one who has any degree of familiarity with the contracting or muscular tissues, will refuse for a moment to regard the fibres of the iris, both circular and radiating, as of this nature. The peculiar form and appearance of the elongated nuclei, and the minutely dotted or granular aspect of the fibres, the granules being often arranged in a somewhat regular manner, are sufficiently characteristic of this structure, independently of the separation of the fibres into elongated cells, described by Kölliker.

inch focus, of the existence of granular fibres, which contain nuclei of the same description as in other unstriated muscular parts of the body, the fibres being finer, and the nuclei more frequent and rounder, than in the muscular substance of the intestine. In one iris, which I have under examination, in which both the sphincter and radiating fibres appear to be developed in an unusual degree, I find that the radiating fibres may be traced over the sphincter to the margin of the pupil on both surfaces of the iris, but in greatest quantity anteriorly. These radiating fibres appear thus to enclose the sphincter muscle in slings or loops, an arrangement which we may suppose would prove most effective in pulling the inner margin of the iris outwards in dilatation.

But even if anatomical examination had been less satisfactory than it has recently been, the observation of the contractions of the iris in circumstances which do not admit of their being referred to any other cause than that of muscular contractility, would be amply sufficient to establish the nature of the two sets of fibres which exist in the iris. The application of a galvanic stimulus to the iris of an animal immediately after death, it is well known, is generally followed by contraction of the pupil, and alternate relaxation and contraction may be observed to be induced for some time by the repeated application and removal of the stimulus. But Professor Kölliker has made the additional interesting observation (Mikroskop. Anat., vol. ii., p. 642), that when in a recently killed rabbit, from the eye of which the cornea has been quickly removed, the sphincter of the pupil is carefully cut away, the application of the galvanic stimulus to the iris then occasions a dilatation of the pupil by the contraction of the radiating fibres, as distinct as that which is occasioned by the irritation of the exposed sympathetic nerve in the neck, and in every way as distinct as the contraction produced by the direct irritation of the iris when the circular fibres are entire. This experiment not only proves directly the muscular nature of the radiating fibres, but also shows, what might indeed have been inferred from other circumstances, that the circular fibres form a more powerful muscle than the radiating ones, and are capable, in the direct application of stimulus to the iris, of overcoming the latter.

We may, therefore, regard it as fully established, that the iris possesses two muscles which stand in the antagonistic relation of a contractor and dilator of the pupil. We shall hereafter see the different relations in which these two muscles have been shown to stand to the nervous system.

It is well known that, according to the observations of Valentin, Bowman, and others, the muscular fibres of the iris of birds, and also of certain scaly reptiles, are of the striated kind; and it is generally believed that the motions of the iris are subject, in these animals, to the influence of the will. We may afterwards consider, in how far the motions of these muscles may be really

different from those of the human eye; but I may state that I have found, as Brücke and Kölliker have done, the striated fibres very apparent, in the radiating or dilating, as well as in the circular or contracting muscles, of the bird's iris.

In the human eye, the radiating fibres, like the base of the iris itself, are attached to the inside of the line of junction of the cornea and sclerotic, or to a layer of elastic fibrous substance placed inside the circular sinus or canal of Schlemm, while the uvea or pigment layer behind the fibrous portion of the iris is continuous with the similar structure of the choroid membrane prolonged from the inner ends of the ciliary processes. But in birds, as I have observed it, the iris has a comparatively loose attachment to the external coats of the eyeball, and is chiefly fixed to the ciliary processes or choroid membrane; and, indeed, in mammalia, and in man, the radiating fibres scarcely reach the base of the iris, and have a far less firm attachment externally than the fibres of the ciliary muscle have near the same line; so that the base of the iris may probably be withdrawn to some distance from the line of its attachment to the outer coats of the eye.

Ciliary muscle.—The more recent researches of Bowman, Brücke, and other anatomists, have established, with equal certainty as in the iris, the existence of a small mass of muscular fibres of the unstriated kind in the body, situated between the ciliary processes and adjacent part of the sclerotic coat, and which has been variously named, but is best known in this country as the ciliary ligament. It is now generally admitted by anatomists, that this substance, occupying the triangular space between the junction of the cornea and sclerotic and the front of the choroid coat, consists of two parts, viz., a narrow fibrous ring of lighter colour attaching it anteriorly, and a broad or spreading fibrous part of a pinkish grey colour passing back to the surface of the choroid membrane. To the muscular fibres in this body, Brücke applies the name of tensor choroideæ, to which Mr. Bowman's name of ciliary muscle may be preferred, as not involving any statement as to its action, which, though it may probably be that of drawing forward a part of the choroid, must still be regarded as imperfectly known. The fibres of the ciliary muscle radiate from a narrow line situated near the inner side of the canal of Schlemm, close to the same place from which the radiating fibres of the iris proceed, and they spread backwards and outwards over the external surface of the ciliary processes, nearly in their whole extent. By microscopic examination, these fibres are found to belong to the unstriated variety of muscular fibre, the characters of which they possess in a still more obvious degree than those of the iris. Mr. Lister has described them well in the paper previously referred to, and I have had no difficulty, in several specimens of the human eye, in tracing their course and connections, and in observing with the microscope the features of the unstriated

muscular structure. The easiest way of observing the relations of this small muscle, is to cut out, with a sharp pair of scissors, a narrow portion of the cornea and sclerotic, with the adherent part of the iris and choroid membrane, from the front of the eye, and to examine this specimen in profile, or on the edges of the section, separating the parts slightly with needle points. In birds, it would appear that, in addition to the muscle discovered by Sir Philip Crampton (Thomson's Annals of Philosophy, 1813, vol. i., p. 170), there is another muscle situated farther back on the choroid, discovered by Brücke (Müller's Archiv. for 1846, p. 375), and which that author regards as the true tensor of the choroid membrane, while according to him the muscle of Crampton acts on the osseous plates. In both of these muscles, as in the iris of the same class of animals, the muscular fibres are of the striated variety. This I have myself recently confirmed by observation. Besides these muscular parts connected with the choroid membrane, Mr. Rainey has described, in some mammiferous animals (Proceedings of Royal Society of London, June, 1851, and Philosophical Magazine, May, 1851), a striated muscular structure pervading the inner layer of the choroid membrane through its posterior half, which he supposes may be connected with adjustment, as he does not admit the muscularity of the ciliary body. But this observation has not been confirmed in a careful examination of the choroid membrane of the same animals by Henle, Kölliker, and others. More recently, however, Wittich has pointed out in birds, the existence of such a muscular structure in the posterior part of the choroid membrane, though he was unable to detect any similar structure in the choroid of mammalia. There can be no doubt, therefore, that in the ciliary muscle of the human eye, as well as in that of most animals, a structure exists capable of producing motion of the parts to which it is attached. It will afterwards appear that its action by itself, or along with that of other parts, is not exactly that which Porterfield and others had, with great probability, supposed, of advancing the lens by its action upon the choroid behind it, but of a different kind, leading to a change of curvature of the surface of the lens, by a mechanism the details of which do not as yet appear to be clearly determined.

2. *Motions of the Iris and Ciliary Muscle.*

It has long been known that the influence of light in producing contraction of the pupil operates by reflex action through the retina, optic nerve, and part of the brain, upon the roots of the third or common oculo-motor nerve; for the action of light ceases to call forth the contraction of the pupil if either the third pair or the optic nerve be divided, or if the place of their connection in the anterior pair of corpora quadrigemina be destroyed; and the afferent action of the optic nerve has been farther shown by the

experiment of irritating the central end of the divided nerve, in which case contractions of the pupil ensue in the same manner as when light falls upon the retina. All experimenters concur in stating that mechanical or other irritation of the trunk of the third pair of nerves is followed by contraction of the pupil, and that the division of the same nerve is equally constantly attended by dilatation of the pupil. This dilatation has also been observed as an invariable symptom of paralysis of the third nerve, so that no doubt can be entertained as to the fact that this nerve regulates or influences the motions of the orbicular muscle or contracting ring of the pupil.

It is thus manifest that the motor nerves, by which the contractions of the pupil are produced, proceed from the inferior division of the third nerve, by its communicating branch with the ophthalmic ganglion to the ciliary nerves; and, in accordance with this anatomical fact, it is well-known that there is a frequent association of the contracting motions of the pupil with the actions of those straight muscles and the inferior oblique which derive their motor nerves from the lower division of the third pair, and more especially with those of the internal recti, which produce convergence of the optic axes when viewing near objects. This association is very general, and in most persons it is almost impossible to move the iris (as in changes of adjustment), without, at the same time, throwing the external muscles of the eyeball into contraction. But it would appear from many circumstances, and more especially from the observations of J. Müller and Volkmann (see article 'Vision' in Wagner's Handwörterbuch der Physiol., vol. iii., p. 308), that the association is not invariable, and that the internal movements of the eye may be exerted independently of those of the external muscles. This is shown more particularly by the experiment, that in looking at a distant object, as a star, with one eye, while the hand covers the other, as soon as the hand is removed, a double image of the object is perceived, which proves that the axes of the eyes have not previously been made to meet upon the object viewed. There seems to be some reason, therefore, for admitting that we possess a certain amount of voluntary power over the contracting muscle of the pupil, although this contraction is usually of an associated kind; and there seems to be great probability that the amount of this voluntary power may differ in different persons, as it does in different animals.

Differences, indeed, have been observed in the connection and distribution of the nerves proceeding to the eyeball, such as the connection of the sixth and third nerves referred to by Dr. Struthers in his Anatomical Observations, which may be connected with a various amount of the voluntary power exerted over the motions of the pupil.

With regard to the voluntary influence over the muscles of the

iris, Valentin remarks (Physiol., Vol. II., p. 778), "Although no muscle possessed of only plain fibres is subject to the influence of the will, yet some are indirectly susceptible of that influence by association with true voluntary muscles. The iris is a good example of this. When, for example, we move both eyes to the side, in which the internal rectus acts in one eye, and the external rectus in the other, no change occurs in the size of the pupil; but when we converge the two eyes, the pupils contract, and they again expand when we remove the convergence, as in near and distant vision." From this he thinks we may conclude that the simultaneous energy which produces the contraction of the two internal recti muscles excites also the circular or contracting muscle of the pupil, while the preponderance of the external recti has the opposite effect of dilatation. Valentin states farther, "We may by practice acquire the power of contracting and dilating the pupil of one eye kept fixed on an object, while the other is closed; but the art consists in this, that we move the axis of the closed eye in and outwards, and the pupil of the open eye moves in agreement with that of the other which is closed. The chief difficulty, therefore, consists in keeping the open eye at rest, while the closed one moves. This shows, however, that the contraction of the inner rectus of one side is sufficient to cause the consentient contraction of the pupil of both eyes, when not balanced by the action of the external rectus."

These modifications of the operation of nervous influence upon the motions of the iris appear to be in some manner connected with the ciliary ganglion, but the nature of the action of this ganglion is as yet entirely unknown.

Although many of the phenomena of dilatation of the pupil might be explained on the supposition that the radiating fibres are possessed only of physical elasticity, yet the anatomical facts already stated, and all recent and accurate physiological and pathological observations, indicate the muscular nature of these fibres, and point to a very remarkable dependence of their contractions on a different nervous centre from that with which the motions of the contracting muscle are connected. This difference has of late attracted considerable attention among physiologists and pathologists.

It had long ago been observed by various experimental physiologists, that in dogs the division of the vagus and sympathetic nerves in the neck was followed by a contracted state of the pupil.* Dr. John Reid showed, in 1839, that this effect depends more particularly on the injury of the sympathetic nerve, which in dogs is closely united with the vagus in the neck, and he fully demonstrated, by experiments on dogs and cats, that injury of

* As by Petit in Hist. de l'Acad. Roy., Paris, 1727. Mollinelli in Comment. Bononiens., 1755; and Dupuy, in Journ. de Med., &c., 1816.

the superior cervical ganglion, or of the principal trunk of the sympathetic nerve in the neck, is followed very soon by contraction of the pupil. In rabbits, however, Dr. Reid did not observe the same result from injury of the sympathetic nerve, and with this result the experiments of Cumerer and Pommer agree. Valentin, on the other hand, found that although, as Dr. Reid had observed, no effect was produced on the iris of rabbits by division of the vagus or sympathetic in the middle of the neck, yet the removal or destruction of the superior cervical ganglion of the sympathetic, or of the nervi molles on the carotid, was in the rabbit, as in the dog or cat, followed by contraction of the pupil. From these and other facts, Valentin deduced the conclusion that the iris derives its motor filaments from two sources,—viz., from the third pair, or common oculo-motor, and from the spinal nerves which join the sympathetic.— See Valentin, de Functionibus Nervorum, 1841, and John Reid's Researches, 1848, p. 303.)

The difference that had been observed by himself and others between the effects of injury of the vagus and sympathetic nerves on the iris in the dog and rabbit, are explained by Dr. Reid by the fact, that in the rabbit the motor filaments join the sympathetic from the upper cervical nerves, while in the dog they run into both the sympathetic and the vagus lower down in the neck; a view which is confirmed by the experiments of Valentin, which show that the division of the nervous twigs connecting the sympathetic with the spinal nerves has the same effect as the destruction of the upper part of the sympathetic nerve itself.

The more recent experiments of Budge and Waller confirm the views of Reid and Valentin, and afford more detailed explanations of some of the phenomena. According to these observers, (Comptes Rendus, vols. xxxiv. and xxxv.), the sympathetic nerves reach the iris mainly by union with the ophthalmic division of the fifth pair. These experiments made it certain, not only that the destruction of the sympathetic nerve in the neck caused contraction of the pupil by paralyzing the radiating fibres, but that these fibres are capable of being thrown into contraction, so as to dilate the pupil actively by the stimulation of the sympathetic nerves, or of that part of the spinal marrow from which the motor filaments of the sympathetic are derived, viz., the lower part of the cervical, and upper part of the dorsal spinal marrow. Thus, as stated by Dr. W. Gairdner, "if the spinal cord be destroyed between the fifth cervical and the sixth dorsal vertebræ, contraction of the pupils occurs. If one side only of the spinal cord be destroyed in this region (which Budge and Waller call the cilio-spinal), or if the emerging spinal nerves, or their anterior roots be cut, a similar effect is produced."

It appeared thus to be satisfactorily shown that the size of the pupil is regulated by two muscular forces acting under different

nervous influences, the contraction being produced by the orbicular fibres under the cerebral influence transmitted through the third pair of nerves, and the dilatation by the radiating fibres under the spinal influence transmitted through the sympathetic filaments, which pass from the superior cervical ganglion along the carotid plexus to the ophthalmic ganglion. Valentin (De Functionibus Nervorum, 1841) suggested that this view of the double source of nervous influence, by which the state of the pupil may be affected, might explain the variety in the condition of the pupil arising in certain diseases. Dr. Reid had already referred to an instance of tumour of the neck involving the nerves in which contraction of the pupil existed. Dr. W. T. Gairdner has more lately described an interesting case of aneurism of the aorta projecting into the neck, and occupying a space from the fifth cervical to the second dorsal vertebræ, so as to press upon the connections of the sympathetic nerve with the spinal nerves, in which, during a long time, contraction of the pupil on the affected side occurred; and in relating that case (Edin. Med. Jour., Aug., 1855), he has given an excellent account of the explanation of this symptom from the ascertained physiological facts. There was also an opening from the aneurismal tumour into the spinal canal produced by absorption of part of the vertebræ, which may have caused pressure on the "cilio-spinal" portion of the spinal cord. In the later stages of this case, and for several weeks before death, both pupils were contracted, and it does not appear very clearly to what cause this equality of the pupils was to be attributed; but it appears that while the state of contraction lasted, it depended rather on a state of weakness than of complete paralysis of the dilating muscles of the iris. The more rare cases of disease affecting the spinal cord in which a contracted state of the pupil has been observed, such as that related by Sir B. Brodie, and another by Dr. Budd, as quoted by Mr. Bell (Edin. Med. Jour., July, 1856), are confirmatory of the views now stated.

Notwithstanding the number of interesting facts now referred to, as having been ascertained respecting the mechanism of the motions of the iris, and their connection with the nervous system, we have probably yet much to learn before we can explain many of the phenomena of these motions that have been observed.

It has been observed, for instance, that the pupil is fully contracted in an animal when the carotid arteries are compressed to such an extent as to obstruct the flow of blood through the cerebral and ophthalmic arteries, and that a state of dilatation succeeds upon the removal of the pressure and the restoration of the circulation. (Bernard, Brown Sequard.)

In cases of concussion of the brain the pupil is frequently contracted, while in deep coma it is usually fully dilated.

In ordinary sleep, the pupils of the closed eyes are in a state of

moderate contraction, but in hybernating sleep the pupils are fully dilated. (Otto Funke's new edition of Wagner's Physiology.) In magnetic sleep they are also usually dilated. I find the effect of the inhalation of chloroform to be the full dilatation of the pupils, when the state of anaesthesia is produced.

In most instances, after death, the pupil is considerably contracted, and remains so during the continuance of the rigor mortis; it then gradually passes into a state intervening between contraction and dilatation.

In animals or in man killed by decapitation, the pupils are contracted, though not quite equally in the two eyes, and remain so for several hours or even days, after which they pass into the state of mean dilatation. I have found that in rabbits the division of the medulla oblongata between the occipital bone and atlas causes immediate contraction of the pupils to a considerable degree, and that this contraction is still farther increased, and nearly in an equal degree, by the subsequent destruction either of the brain or of the upper part of the spinal cord.

Injury of the fifth pair of nerves seems to produce somewhat various effects: in man and in the rabbit contraction of the pupil, but in dogs and cats just the reverse, or marked dilatation continuing for weeks, and in both cases the pupils are immovable.

In affections of the retina and optic nerve, the pupil is generally dilated and inactive; but when one eye only is affected, the pupil of that eye as well as of the other may act in obedience to the reflex influence conveyed through the unaffected retina.

The various modifications of form to which the pupil is subject, under the influence of different nerves, are not easily explained: thus, Valentin found that in rabbits the destruction of the inferior plexiform ganglion of the vagus nerve produces, along with contraction, an oval form of the pupil, in which the upper part is smaller and angular; while, if the superior cervical ganglion of the sympathetic nerve has been destroyed, the contraction, which is fuller, is attended with the production of an oval form, with the small or angular end downwards. In these cases, touching the surface of the eye to remove fluid was always attended with a slight dilatation of the pupil.

Ruete, in his learned treatise on the application of anatomy, physiology, and pathology to Ophthalmic Medicine, in R. Wagner's Handworterbuch, vol. iii., part 2, gives reasons for regarding many of these influences as of a reflex character. He states that if the wires of a rotating electro-magnetic battery be applied to the eye of an animal in which the cerebral influence has been destroyed, but the sympathetic nerve left entire, dilatation of the pupil occurs; while in a living animal the same stimulus occasions contraction of the pupil. This he considers as analogous to the action of the rotating machine in causing the heart's action to cease when applied to the vagus nerve; and he regards the

trigeminus or fifth nerve as standing in the same relation to the sympathetic motor nerves of the iris, as the vagus does to the motor nerves of the heart; for, says he, just as we find with the heart, a slight stimulus of the rotating machine applied to particular branches of the fifth nerve which join the ciliary ganglion causes dilation of the pupil, by action on the sympathetic nerves, but the full force of the machine applied to this nerve causes contraction of the pupil, by acting on the oculo-motor nerve.

In corroboration of this view, Ruete mentions more than one case in which slight injuries of the fifth nerve were attended with a dilated condition of the pupil; and he suggests farther, that in these modifications of the nervous influence of the sympathetic nerve may be found the explanation of the varying state of the pupil which accompanies different classes of diseases, the effect of the passions or states of the mind, and various other states of the economy.

The remarkable property of belladonna or atropine, as also of hyoscyamus and stramonium, to dilate the pupil, which is a very serviceable assistance to the practical oculist, occasions much difficulty to the physiologist in attempting to give an explanation of the mode of action of these narcotics, in accordance with the known anatomical and physiological history of the structures involved in their operation.

It has been ascertained that so small a quantity as a three-thousandth part of a grain in solution, applied to the conjunctiva of one of the eyes, causes dilatation of the pupil in the course of a quarter or half an hour; but as the pupil of the other eye retains its natural state, it must be held that the action is entirely local, or through the nervous and muscular structure of the eye to which the narcotic has been applied. It is rare, indeed, unless a large quantity of a strong solution has been employed, to observe the dilating action spread from one eye to the other. But the case is quite different when the narcotic has been introduced into the system in sufficient quantity, by application into a wound or by being taken into the stomach. Thus it appears that this narcotic takes effect or produces dilatation in both eyes, by its operation through the circulation as soon as it is absorbed.

The observations of physiologists do not appear, as yet, to have fully determined through what nervous channel this takes place, or, in other words, whether it is by the paralysis or weakening of the action of the sphincter muscles, or by stimulating the action of the dilators of the pupil, that this very remarkable effect is produced.

This subject has recently received a short but interesting discussion in the Edinburgh Medical Journal, from the observations of Mr. B. Bell and Dr. Harley. In the Quarterly Report of Cases treated in the Ophthalmic Hospital in Edinburgh, by Dr. Hamilton and Mr. Bell, (No. for July, 1856,) the latter author has ap-

prided some observations on the action of belladonna and atropine, in which he adopts the view (to which recent researches seemed most naturally to lead) that these narcotic substances act by stimulating the radiating, rather than by paralysing the circular fibres of the iris. Dr. Harley, of University College, London, (Same Journal, No. for November, 1856) while he admits the difficulty of obtaining conclusive evidence on this point, was induced to adopt an opposite opinion, from an experiment performed by himself in concert with Dr. Sharpey, in which they found that, on dividing the sympathetic nerve in the neck of a cat, the pupil, which became permanently contracted immediately after the division, was not affected by the immersion of the upper part of the divided nerve in a solution of atropine.

Mr. Bell, in the paper already referred to, and in a subsequent communication to the same Journal, for December, 1856,) rests his opinion mainly on the fact, observed by Dr. Struthers, (Anat. and Physiol. Observations, 1854, p. 104,) and confirmed in a number of instances by himself and others, that in well-marked cases of paralysis of the third pair of nerves, the pupil still remains dilatable by the local application of solution of atropine, to as great an extent as in other instances in which no paralytic affection existed.

I will not, at present, dwell on the consideration of the difficult question in what manner the narcotic solution arrives at the nerves or muscles of the iris on which it produces its effects. It seems to be agreed upon by experimenters, that it requires to be absorbed into the circulation in order to produce dilatation. But I will remark that all observation and experiment tend to show that the narcotic substance may operate in two ways, viz., by local action as in one eye, when applied locally in moderate quantity, and by general action, that is, when introduced into the system by absorption from the stomach, or applied locally in such quantity as to pervade the general circulation. Dr. Harley's experiments, as well as those of many others, seem fully to demonstrate this view.

But it appears to me that the negative result of the experiment by immersion of a portion of a nerve in the narcotic solution, does not fully warrant the conclusion deduced from it by Dr. Harley, that atropine does not operate by the stimulation of the nerves of the radiating fibres, because it is well known that, in other instances, narcotic action, by direct application of the poison to a nerve, is confined to that portion of the nerve which has been immersed. To render the deductions from this experiment conclusive, it would be necessary that we should observe and know the effect of the application of the narcotic to the nervous centres with which the respective nerves whose functions are involved in doubt are connected, and farther, that we should ascertain the effects of these poisonous agents on the nervous centres through the afferent nerves. Dr. Harley has related various experiments (Lancet, 1856, Vol. II., p. 40), from which it appears that the direct application of strychnia to the substance of the spinal cord

was not followed by any of the physiological effects known to proceed from the introduction of that poison into the system: and it may be presumed that the same negative result would follow the application of atropine to the spinal cord. It is well ascertained that the stimulus exciting tetanic contraction from strychnia acts from the spinal marrow through the motor nerves on the muscles, as the division of the nerves causes an immediate cessation of the spasms in the muscles to which they were distributed; but, as has been well suggested to me by my colleague, Professor Rainy, to ascertain distinctly the manner of this action it would be necessary to perform an experiment which would enable us to distinguish between the operation of the sensory and motory roots of the nerves.

There are two principal difficulties which oppose the formation of a decided opinion on this subject. The first of these is to determine whether, in the cases referred to by Mr. Bell and others, the paralysis of the third pair has been complete or only partial, for it is obvious that in the latter case, as Dr. Harley remarks, the application of a narcotic, by increasing the extent of the paralysis, may produce increased dilatation of the pupil. The second difficulty arises from the circumstance already adverted to, that we have not yet the means of determining whether the action of the narcotic is directly on the distributed extremities of the motor nerves and the muscular fibres, or mediately on these structures through the nervous centres. Mr. Bell has adopted the view, which the foregoing observations render very probable—that the action of the narcotic substances may be of a reflex nature, through the afferent or sensory nerves, which probably belong to the fifth pair; but a renewed series of experiments seems necessary, in order to distinguish between the local and general modes of action of atropine in dilating the pupil.

Mr. Bell has suggested, that if the action of atropine be, as held by some, of the nature of a paralysis of the circular fibres through the third pair of nerves, and not, as he is inclined to believe, an incitation of the radiating fibres through the sympathetic, the division of the latter nerve in the neck of an animal in which the pupil had been previously dilated by atropine, should not be followed by contraction of the pupil.

I have performed several experiments with a view to the elucidation of this point; but they have not been attended with results sufficiently marked to permit me to regard them as decisive.

In the animals (several rabbits and one dog) on which I experimented, a full dilatation of one pupil was first produced by the local application of a solution of atropine, and the vagus and sympathetic nerves were then divided on both sides of the neck; in the same manner, and with the same precautions and differences according to the animals, as in the experiments of Reid and Valentin, so as to obtain the contraction of the pupils. In all

instances a strong contraction of the pupils followed the division of the nerves; but in the majority of instances the contraction was not quite so full in the pupil previously dilated by atropine, as in the other not so treated.

I found also, by a number of experiments in the dog, cat, and rabbit, in which animals the pupil of one eye had been previously dilated by atropine, that the inhalation of chloroform produced, during the continuance of the full anæsthetic effect, as complete a dilatation of the pupil in the unaffected eye as the atropine had caused in the other; and that this latter pupil was in general little changed, or only very little more dilated than before. During violent struggles of the animal previous to the occurrence of the full insensibility, it is to be observed, considerable contractions of both pupils occurred; and, when dilatation had been produced, as the animal recovered from the effects of the chloroform, while the pupil to which the atropine had been applied remained nearly of the same size as before, the other one gradually returned to its natural state of contraction.

I found farther, that in killing animals of which one pupil had been dilated by atropine, by dividing the medulla oblongata between the occiput and atlas, while both pupils ultimately contracted to a considerable degree, the contraction of the pupil dilated by atropine was about a minute later of coming on, and was not so full as that of the other eye. It appeared to me in two experiments that the amount of contraction in the two eyes (dilated and non-dilated) was more nearly equal when, after having divided the medulla oblongata, the upper part of the spinal marrow was rapidly destroyed, than when in the same previous circumstances the brain was immediately removed.

Although there are many complicating circumstances in these experiments which must prevent our forming a decided opinion from them, the general result appeared to me somewhat favourable to the view that atropine operates upon the pupil by some action through the nerves of the radiating fibres, rather than by inducing paralysis of the nerves of the sphincter muscle.

The pupil stands balanced, as it were, between the action of the circular and radiating muscular fibres, and these fibres are under the influence of two different portions of the nervous centres: the circular, viz., under that of the corpora quadrigemina and some other parts of the brain; the radiating, under that of a part of the cervico-dorsal portion of the spinal cord. The fact that the motions of the iris are under the control of two kinds of nervous influence, first ascertained by the experiments of J. Reid and Valentin, was more fully confirmed by the experiments of Guarini, (Annal. Univ. di Medic., 1844, and Gazette Medic., April, 1845,) by which it was proved that section of the third pair of nerves is invariably followed by dilatation, and irritation of the same nerve by contraction of the pupil; while the divi-

sion of the sympathetic nerve is as constantly followed by contraction, and stimulation of that nerve by dilatation of the pupil. The further observations of this experimenter, that after removal of the superior cervical ganglion of the sympathetic nerve on one side, the application of belladonna is no longer followed by dilatation on that side, but that the dilatation occurs as usual in the other eye, appears also to favour the view that these agents operate as much by affecting the active dilating forces as by altering the power of the contracting ones.

It is a remarkable fact, stated by Otto Funke, (Wagner's Physiol.), that the dilating effect of belladonna is confined to those animals in which the muscular substance of the iris is composed of the plain or unstriated fibres, and that this substance has not the slightest effect upon the eyes of birds in which the fibres are of the striated kind. We are as yet, however, as the same author remarks, quite in the dark as to the explanation of the reason why the belladonna acts on one set of nerves and not on the other.

Movements of the iris, it is well known, invariably accompany all changes in the focal adjustment of the eye; but it is uncertain to what extent these motions of the iris are essential to the change of adjustment. Some circumstances, indeed, seem rather to show that the iris is only secondarily concerned in this action, which may go on to a certain extent independently of it, and which is very probably most intimately connected with the actions of the ciliary muscle. It appears to be ascertained, at least, that while a fixed adjustment of the focus of the eye is maintained by certain internal actions, the iris may be made to move to a considerable extent by other causes, such as the admission or exclusion of light, &c.

In recapitulation, then, of what has been stated regarding the motions of the iris, it appears that these, when producing contraction of the pupil, may take place in three classes of circumstances:—1st, under the reflex stimulus of light through the optic nerve, by which the quantity of light admitted into the eye is regulated; 2nd, in association with the recti muscles, and especially the internal, not in movements of direction, but only of convergence of the optic axes; and 3rd, also in association with the ciliary muscle, to some extent without the concurrence of the external muscles. In all these motions the brain acts as the centre of reflex or direct nervous influence, by which the motions are excited, and the contracting muscle of the pupil appears to be the active moving power. Against this, however, another force is constantly acting under a different influence, viz., that of the dilating muscle under the influence of the spinal marrow or sympathetic ganglia; but the circumstances under which that influence is exerted, are as yet very imperfectly understood. Its operation appears to be almost constant, so that

whenever the stimuli which act through the cerebral centre are withheld, the dilatation is caused by the spinal and sympathetic influence. The extent to which the sixth pair of nerves may co-operate in this influence is not yet ascertained.

The transitions between the associated and voluntary movements of the iris are by insensible degrees. In general, these movements are only associated or consentient; but I believe that in some instances, as in the case before us, they may assume more or less of a voluntary character. I do not think this inconsistent with what is known of other examples of muscles holding an intermediate place between the voluntary and involuntary, the difference in which depends more immediately upon the properties of the nerves proceeding to them, than on the muscles themselves; and these properties are susceptible, as we know, of very considerable change from exercise, habit, and other causes.

Nothing has yet been ascertained by direct observation or experiment with respect to the motions of the ciliary muscle in man or quadrupeds. It is only, in fact, by its effects in connection with adjustment that these movements have as yet been guessed at. Recent experiments on this subject have led to the interesting result, that a change in the curvature of the surfaces of the lens, more especially of its anterior surface, occurs during the adjustment for near vision. I have fully confirmed these observations, and should now have proceeded to detail them, but that I have already occupied too large a space in connection with this subject. I will reserve my further observations on the subject of adjustment for a future occasion, and will only at present remark that the experiments to which I refer leave no room for doubt, that the change of adjustment for near vision is the most active state, and that for distant vision a return more or less to the passive condition; and further, that as the ciliary muscle is the part more immediately concerned in the change of adjustment, that muscle must pass into a state of contraction for near vision, and of relaxation for distant vision.

These experiments, I may further remark, appear to me still more clearly to show that the iris is not the cause of adjustment, and only as it were accidently associated in its movements with those of the parts which are the immediate agents of the change. It appears, however, that when, as is almost invariably the case, the motions of the iris and ciliary muscle are associated together, and both of them very generally with that of the recti muscles, it is the sphincter muscle alone of the iris which is associated with the active condition of the ciliary muscle, and it is doubtful whether the radiating muscle participates in this association.

It may also be stated, that although it appears, in so far as researches have as yet furnished any data on which to form an opinion, the return of the eye from the state of near adjustment to the more passive state, in which it is adapted for distant

vision, does not seem to be accompanied by any active change other than that of the contraction of the radiating fibres of the iris, yet it cannot be considered as certain that other muscular fibres may not exist which assist in that action. It seems not improbable that in birds the muscular fibres contained in the posterior part of the choroid coat of the eye may have an effect the reverse of the anterior or ciliary muscles; and it is not beyond the bounds of possibility that muscular fibres may yet be discovered in the choroid membrane of mammalia, which assist in the act of adjustment for distant vision, or in bringing back the lens and other structures of the eye from the condition adapted for near to that for distant vision: a change which is generally attributed only to the elasticity of the capsule of the lens and other parts.

In connection with these views, several circumstances connected with Dr. Paxton's case may deserve particular attention. Reserving these for after consideration, I will only at present add that he informs me by letter, in proof of his possessing a greater than usual power of moving the iris independently of adjustment, that he "can fix the eyes upon a near object, and while steadily looking at it dilate the pupil without any effort for adjustment for distant vision; and while continuing to look at a distant object, he can still farther dilate the pupil and contract it at will, without any attempt at adjusting the eye for near vision." This is a power partially possessed by others within my knowledge.

The observation made by Dr. Paxton in the concluding sentence of his statement of his case is also an extremely interesting one, as it seems to show that the most peculiar feature in his case is connected with the active power of dilatation, for, when he required to execute the associated movements of the eyes, he lost the power of producing the extreme dilatation.